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An ESTIMATE of RADIATION DOSES RECEIVED by INDIVIDUALS LIVING in the VICINITY of a NUCLEAR FUEL REPROCESSING PLANT in 1968

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NORTHEASTERN RADIOLOGICAL HEALTH LABORATORY

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	Title
BRH/NERHL 70-1	An Estimate of Radiation Doses Received by Individuals Living in the Vicinity of a Nuclear Fuel Reprocessing Plant
BRH/NERHL 70-2	Liquid Waste Effluents from a Nuclear Fuel Reprocessing Plant (in process)
BRH/NERHL 70-3	Simultaneous Stack and Environmental Monitoring of Airborne Radioactivity at an Operating Nuclear Fuel Reprocessing Plant (in process)
BRH/NERHL 70-4	Calibration and Field Tests of ^{85}Kr Detectors for Environmental Monitoring (in process)

BRH/NERHL 70 -1

An ESTIMATE of RADIATION DOSES RECEIVED by INDIVIDUALS LIVING in the VICINITY of a NUCLEAR FUEL REPROCESSING PLANT in 1968

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Radiological Health
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FOREWORD

The recent growth in the utilization of nuclear reactors for electrical generating plants has brought with it the need for nuclear reprocessing plants that extract usable uranium and plutonium from spent fuel elements. The Bureau of Radiological Health performs a technical review and evaluation of the public health factors of all nuclear facilities and provides technical assistance to State health departments responsible for assessing population exposure and radiation levels in the environment. The Northeastern Radiological Health Laboratory, under the aegis of the Division of Environmental Radiation, has undertaken an environmental survey of the first commercial operating fuel reprocessing plant in the United States.

The technical reports series of the Bureau's regional laboratories and its Division of Environmental Radiation is used to publish the results of research projects and technical evaluations of nuclear facilities. These reports are distributed to State and local radiological health program personnel, Bureau technical staff, Bureau advisory committee members, radiation safety officers, libraries and information services, industry, the press, and other interested individuals. These reports are also included in the collection of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The projected increase in the utilization of nuclear power for electrical generating plants has resulted in both State and Federal public health agencies placing increased program emphasis on the surveillance of nuclear power plants. The Bureau of Radiological Health provides recommended nuclear facility surveillance program information for the guidance of health agencies. In order to provide a better technical basis for environmental surveillance recommendations, a series of field studies have been conducted at operating nuclear facilities to obtain better data on radionuclides in plant effluents and their subsequent distribution in the environment.

This field study around the Nation's first commercial nuclear fuel reprocessing plant was for the purpose of identifying the movement of critical radionuclides through the atmospheric and aqueous environments in relationship to the fuel reprocessing procedures. Technical data obtained from this study will be used to: (1) develop minimum and optimum requirements for environmental surveillance around nuclear fuel reprocessing plants; (2) designate the radionuclides and environmental pathways of greatest dosimetric significance, and (3) provide estimates and measurements of the radiation dose to populations in the area of a facility.

Charles L. Weaver
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ABSTRACT

The public health implications associated with a nuclear facility can be best evaluated in terms of the radiation dose delivered to persons in the vicinity of the facility. This report attempts, by use of the dose commitment concept and surveillance data previously collected, to estimate radiation doses in 1968 to persons in the vicinity of a fuel reprocessing plant from ingestion and inhalation.

The dose commitment accrued in 1968 to a hypothetical "typical individual" is not thought to differ significantly from that for the average adult population in the rest of New York State and is attributable essentially to fallout. This commitment was 77 millirem from strontium 90 to the bone and 1.7 millirem whole body from cesium 137 delivered over a 50-year period.

For the hypothetical "maximum individual" the dose commitment to the bone from strontium 90 is 532 millirem and the first-year dose following ingestion is 38 millirem. The whole-body dose from ingestion of cesium 137 and cesium 134 (mostly from deer meat) is 257 millirem. Preliminary data indicate that the external gamma dose above natural background is approximately 1.2 millirem per year to the "maximum individual." Estimated doses from tritium and krypton 85 were negligible ($\sim$2 millirem/year).

ACKNOWLEDGEMENT

Grateful appreciation is expressed by the Environmental Radiation Activities Staff, Northeastern Radiological Health Laboratory, to the New York State Health Department and the Atomic Energy Commission who provided the radioactivity data for this report. In addition, the encouragement of Mr. Charles L. Weaver and the cooperation of the Division of Environmental Radiation, Bureau of Radiological Health, insured the successful completion of this study.

AN ESTIMATE OF RADIATION DOSES RECEIVED BY INDIVIDUALS LIVING IN THE VICINITY OF A NUCLEAR FUEL REPROCESSING PLANT IN 1968

INTRODUCTION

The public health implications associated with a nuclear facility can best be evaluated in terms of the radiation dose delivered to persons in the vicinity of the facility. The Bureau of Radiological Health, Environmental Health Service, is at present investigating radiation levels around nuclear reactors and around a nuclear fuel reprocessing plant. Nuclear Fuel Services, Inc., processes spent fuel from nuclear reactors on a 3,300 acre site 30 miles southeast of Buffalo, in the town of Ashford, Cattaraugus County, N. Y. The company began to dissolve fuel in April 1966, and, beginning in September 1966, began discharging waste materials. Environmental surveillance around NFS has been performed since 1965 by the New York State Health Department (1). The AEC carries out an independent surveillance program (2). By 1968, methodology and reporting were routine (3), and dosimetric calculations were made with data from this year. In addition to routine sampling, special studies on tritium (^{3}H) and krypton (^{85}Kr) in air were performed in 1967 (4,5) and 1969 (6), and also provide basic information for this paper.

The purpose of the project around Nuclear Fuel Services (NFS) is to characterize completely the atmospheric and aqueous environments in relationship to the fuel reprocessing procedure in order to designate which radionuclides are of greatest dosimetric significance. This is being done through a series of field trips to make specific radiological measurements and through a review of previous surveillance data in an effort to extract dosimetric information. This paper describes the assumptions and procedures for determining radiation doses to persons in the vicinity of Nuclear Fuel Services during 1968 and presents and discusses these doses. Further, it relates the concentration of radionuclides in milk, drinking water, deer meat, fish, and air around NFS and their intake by humans.

External radiation measurements are also discussed. Doses are calculated in terms of "dose commitments"; i.e., the dose delivered (in millirem) to a critical organ during a 50-year period (or during life) from a particular intake. Use of the dose commitment concept provides a means of determining the relative significance of doses due to human intake.

The internal radiation dose commitment for an individual in a population group, due to a specific radionuclide, is the product of (1) the factor for converting activity intake to dose, (2) the weight or volume intake of the media per individual per unit time, and (3) the concentration of the radionuclide per unit weight or volume of media. The dose commitment concept applied to the population of the northeastern United States for the years 1961-1968 has been described in detail elsewhere (7). Other investigators have employed a similar method in the estimation of population doses in the environs of a nuclear facility (8).

DOSE COMMITMENT FACTORS

Selection of factors for converting activity intake to dose has been previously described in detail and is beyond the scope of this presentation (7). However, it is pertinent to briefly discuss dose variables which influence the selection of dose commitment factors. Dose commitment factors for airborne tritium and krypton 85, which were not included in the earlier work, are presented in more detail.

Selection of factors for converting activity intake to dose requires consideration of a variety of age dependent variables such as: effective energy and half-time of the radionuclide in the organ of reference, fraction of intake reaching the organ of reference, and organ mass. Furthermore, factors employed in the calculation of radiation dose also vary depending on the mode of intake and the solubility of the radionuclide.

Selection of radionuclide and population groups for which dose commitments are calculated is constrained due to limitations in the data available from environmental networks. For complete radiological evaluation one should be concerned with all population groups, since that group subject to the greatest radiation exposure is not always immediately discernible. However, due to limitations in the availability of data, doses have been calculated for only two population groups. The first designated as a "typical individual," is a hypothetical adult individual ingesting "average" concentration of specific radionuclides based on local environmental surveys. The second group, represented by a

hypothetical "maximum individual" is assumed to ingest half the dietary intake quantities that the "typical individual" ingests. This intake is supplemented by deer meat from animals caught onsite or near NFS and personally caught fresh fish from the mouth of Cattaraugus Creek. This assumption was made because it is unlikely that the "maximum individual" would ingest the same quantities of food as a "typical individual," and in addition, deer and fish. A more likely case would be that half his diet would be from hunting and fishing. The radionuclide content of the diet, deer, and fish, the "maximum individual" ingests is assumed to contain the "maximum" concentration of specific radionuclides. Doses from tritium and krypton for the "typical individual" are based on exposure to average air concentrations of ^{3}H and ^{85}Kr over a 168-hour week. For the "maximum individual" these doses are based on exposure to the estimated maximum annual air concentrations of ^{3}H and ^{85}Kr which are assumed to be present 1.5 km from the plant at the property line. This point being the closest that there might be an inhabited dwelling. A 168-hour per week exposure is assumed.

Although all fission products and transuranic elements may be potential human hazards under specific environmental conditions, the radionuclides ^{90}Sr, ^{137}Cs, ^{134}Cs, ^{60}Co, ^{106}Ru-Rh, ^{3}H, and ^{85}Kr are those for which data on concentrations in milk, food, and air around NFS are available. Dosimetric evaluations in this paper will be limited to these radionuclides alone.

Since radionuclides incorporated into the food chain are likely to be soluble, this physical state was assumed for all radionuclides present in milk, food, and drinking water.

For radionuclides having short effective half-times in the organs of interest, the majority of the total dose commitment is delivered during the first year after intake. Radionuclides with effective half-times in an organ of 100 days or less (i.e., ^{137}Cs, ^{134}Cs, ^{60}Co, ^{106}Ru-Rh, ^{3}H, and ^{85}Kr) deliver 90 percent of their total deliverable dose during the first year. Therefore, for the above radionuclides, the dose delivered in the first year after intake and the dose commitment (i.e., 50 years of lifetime dose) are equivalent. For ^{90}Sr approximately 7 percent of the dose commitment is delivered in the first year after intake (11).

Dose factors used in this paper have all previously appeared in the published literature. The dosimetric models for ^{90}Sr, ^{137}Cs, and ^{3}H (ingestion) and the modifications necessary for application of the models to environmental radioactivity have been previously discussed in great detail (7). Dose commitment factors for ^{134}Cs, ^{60}Co, and ^{106}Ru-Rh also appear in the literature (12). The values used in a model for organ mass, effective energy and half-life and radionuclide transfer from diet to the organ of interest are those recommended by the ICRP (13).

Some further explanation is required concerning the dose commitment factors for ^{3}H and ^{85}Kr in air. The major route of exposure of these radionuclides by humans is by inhalation and skin absorption for ^{3}H and by submersion in air for ^{85}Kr. The dose commitment factors used, as stated in the reference (14), are: $3.6 \cdot 10^{4}X$ for ^{3}H and $4.0 \cdot 10^{4}X$ for ^{85}Kr for a 168-hour week, where X is the radionuclide concentration in $\mu Ci/cm^3$. The concentration in the reference is stated in terms of $\mu Ci/cm^3$ of air and the estimated dose is calculated in rem per week. These equations are then converted to dose per year instead of dose per week ($\cdot 52$); millirem instead of rem ($\cdot 10^{3}$); and μCi/liter instead of $\mu Ci/cm^3$. When the radionuclide concentration is in terms of μCi/liter, the term X_a is used in the equation. The above conversions yield dose commitment factors for ^{3}H and ^{85}Kr of $1.87 \cdot 10^{6}X_a$ and $2.08 \cdot 10^{6}X_a$ respectively. The short biological half-times of ^{3}H and ^{85}Kr in the body make the dose delivered in the first year after exposure comprise the entire dose commitment from these radionuclides. Of course, continuous plant operation would lead to continuous exposure to these radionuclides.

Factors for relating activity intake to dose commitment, in terms of millirem dose per 50 year (or life) are presented in table 1. These factors relate activity intake to dose for a single intake situation. A continuous intake situation can, however, be viewed as a series of discrete intakes. This is valid if variation in activity intake during the period of intake is minimal, if metabolic and ingestion factors during the period of intake and dose commitment remain constant, and if the intake period is short relative to the period for which the dose commitment is being calculated.

ESTIMATES OF DIETARY INTAKE AND EXPOSURE TIME PERIOD

Direct measurement of dietary intake is not available for populations in the vicinity of Nuclear Fuel Services. Measurement of radionuclide milk concentrations, however, provides an indirect measure of total radionuclide intake. Extensive studies in New York City indicate that in 1968 the contribution of ^{90}Sr intake from milk was 37 percent of the total ^{90}Sr intake (15). This relationship can then be used to estimate total ^{90}Sr intake from milk data alone. Similarly, the intake of ^{137}Cs from milk in late 1967 (Chicago) was 30 percent of the total ^{137}Cs intake in the whole diet (16). The intake of ^{3}H from milk to the total diet is assumed to have the same ratio as the liquid intake from milk to the total liquid intake (9) (i.e., 40 percent). These data are used to estimate the total dietary intake of the above radionuclides from their reported levels in milk.

Table 1. Factors for calculating dose commitments

Radionuclide[a]	Critical organ	Mode	Dose commitment factor[b] (millirem per 50 year per μCi intake)
^{90}Sr (7)	Bone	Ingestion	$8.4 \cdot 10^3$
^{137}Cs (7)	Whole body	Ingestion	$0.06 \cdot 10^3$
^{134}Cs (12)	Whole body	Ingestion	$0.08 \cdot 10^3$
^{60}Co (12)	G.I. tract	Ingestion	$0.04 \cdot 10^3$
^{106}Ru-Rh (12)	G.I. tract	Ingestion	$0.195 \cdot 10^3$
^{3}H (7)	Whole body	Ingestion	0.13
^{3}H (14)	Whole body	Inhalation and skin absorption	[c] $1.87 \cdot 10^6 X_a$
^{85}Kr (14)	Whole body	Submersion in air	[c] $2.08 \cdot 10^6 X_a$

[a] Reference from which dose model was obtained in parenthesis.

[b] Dose commitment refers to the dose delivered (in millirem) to a critical organ during a 50-year period (or during life) from a particular intake.

[c] X_a (concentration is in terms of μCi/liter) dose is in terms of millirem delivered for the first year after exposure which in this case is analagous to the dose commitment.

Estimates of maximum and average intakes of deer meat are based on several discussions with deer hunters and reflect personal opinion. Intakes of fish also reflect conversations with local sportsmen in earlier dosimetric studies at Richland, Wash. (10). These figures are in agreement with the dietary intake studies conducted by the USDA of the fish and fish products intake of commercial fishermen (17).

As previously stated, the "typical individual" and the "maximum individual" are presumed to be exposed to ^{3}H and ^{85}Kr concentrations for the same period of time (168 hours per week) albeit at different concentration levels.

A summary of dietary intakes and exposure periods appear in table 2.

Table 2. A summary of yearly dietary intakes and exposure times

Media	Typical	Maximum
Milk	310 liter	380 liter
Deer	2 kg	50 kg
Fish	5.5 kg	40 kg
Drinking water	440 liter	730 liter
Air	8,736 hours	8,736 hours
River bank	0 hours	200 hours

TREATMENT OF DATA AND LIMITATIONS

Samples for analysis of ^{90}Sr, ^{137}Cs, and ^{3}H in milk were obtained from ten farms in Cattaraugus County, N. Y. For 1968, a total of 180 samples were analyzed by the State of New York Department of Health by radiochemical and/or gamma spectrometric analysis (1). About one-quarter that number of public drinking water samples were analyzed in the same year by the AEC (2).

Analytical errors in radiochemical analysis are usually between 5 and 10 percent. Sampling errors are difficult to evaluate. However, variations in results for ^{90}Sr and ^{137}Cs in milk, averaged over the northeastern United States, yield standard deviations which are, in most cases, less than 25 percent of the mean value; although in several instances standard deviations as high as 50 percent of the reported means have been encountered (7). Variations in data around NFS, representing a much smaller sample size, can be expected to reflect ranges in results at least as great.

Radionuclide levels in deer samples, 14 in number during 1968, represent concentrations in the meat only. Unfortunately, due to sample preparation techniques, this is not the case for fish samples (9 during 1968), and the level represents radionuclide concentrations in whole fish. The deer meat samples were obtained from animals throughout Ashford Township; the maximum value was, however, from an animal killed onsite. All fish

samples were caught at the mouth of the Cattaraugus Creek. In addition to ^{90}Sr and ^{137}Cs, these samples were analyzed for ^{134}Cs, ^{60}Co, and ^{106}Ru-Rh. Because ^{90}Sr tends to concentrate in bone, the whole fish sample when used to estimate dose would tend to overestimate the dose from ^{90}Sr. Tritium was not analyzed in fish flesh, and it is assumed that a reasonable estimate of its concentration in fish is the same as its concentration in surrounding water (i.e., ^{3}H in the environment and fish assumed to be in equilibrium). Doses are calculated from the average and maximum concentrations of specific radionuclides in a media over a 1-year (1968) period of time.

Airborne levels of ^{3}H in the environs of NFS were not available for 1968 and were indirectly obtained from 1967 surveys. A study during that year determined the tritiated moisture content in 700 air samples around NFS (4). To convert these values to ^{3}H in air, calculations were made for the weight of water in air (based on 25° C and 50 percent relative humidity) and the density of air; so that the concentrations of ^{3}H per liter of air is $1.18 \cdot 10^{-5}$ times the concentration of ^{3}H per liter of moisture. The large quantity of data from this survey was further analyzed and weighted for variations in the yearly wind rose pattern yielding an estimate of average ^{3}H concentrations over a 1-year period. An estimation of the maximum annual ^{3}H air levels present near a point 1.5 km from the plant at the property line was obtained from the above study. This is the closest habitable dwellings might be established without land sale by the plant.

Similar treatment was accorded ^{85}Kr. Average ^{85}Kr levels had been directly determined in 1968 (5 measurements) (5). The recent evaluations performed by the Northeastern Radiological Health Laboratory provide estimates of the maximum annual concentration to which the "maximum individual" might be exposed. This measurement was obtained for a 3-hour period during reactor fuel dissolution. Based on wind rose data, ^{85}Kr concentrations could not be constant in any single direction (octant) for more than 20 percent of the time; and this factor is also considered in estimating the maximum concentrations over a year's period of time. A yearly stability profile assumed 33 percent of the time in each of the three following stability conditions: Moderately to Extremely Stable, Slightly Stable, and Slightly Unstable. The maximum annual ^{85}Kr concentration has been estimated for a point 1.5 km from the plant at the property line.

Results of environment sampling used to calculate dose commitments appear in table 3.

Table 3. Concentrations of radionuclides in environmental media collected around NFS in 1968 (μCi/liter or μCi/kg)

Radionuclide	Media	Average	Maximum
^{90}Sr	Milk	$11 \cdot 10^{-6}$	$21 \cdot 10^{-6}$
	Deer[a]	$11 \cdot 10^{-5}$	$54 \cdot 10^{-5}$
	Fish[b]	$34 \cdot 10^{-5}$	$64 \cdot 10^{-5}$
^{137}Cs	Milk	$27 \cdot 10^{-6}$	$12 \cdot 10^{-5}$
	Deer	$13 \cdot 10^{-3}$	$67 \cdot 10^{-3}$
	Fish	$63 \cdot 10^{-5}$	$36 \cdot 10^{-4}$
^{134}Cs	Deer	$26 \cdot 10^{-4}$	$12 \cdot 10^{-3}$
^{60}Co	Deer	--	$90 \cdot 10^{-6}$
	Fish	$21 \cdot 10^{-5}$	$30 \cdot 10^{-5}$
^{106}Ru-Rh	Fish	$85 \cdot 10^{-5}$	$21 \cdot 10^{-4}$
^{3}H	Milk	$<12 \cdot 10^{-4}$	$23 \cdot 10^{-4}$
	Deer	$30 \cdot 10^{-3}$	$46 \cdot 10^{-3}$
	Fish	$12 \cdot 10^{-3}$	$50 \cdot 10^{-3}$
	Drinking water	$< 3 \cdot 10^{-3}$	$10 \cdot 10^{-3}$
	Air[c]	$3 \cdot 10^{-8}$	$8 \cdot 10^{-8}$
^{85}Kr	Air	$23 \cdot 10^{-9}$	[d]$13 \cdot 10^{-8}$

[a]Deer - meat only.

[b]Fish - whole fish.

[c]Survey carried out in 1967.

[d]Survey carried out in 1969.

Studies by the AEC (2) show the mean results of TLD monitoring at five locations around NFS to be less than 4 millirem[1] (at the 99-percent confidence level) above background for two monthly periods during 1968 (October 6th through November 15th, and November 15th through December 15th). One location may have been as high as 5 millirem above background[2] for an approximate 1-month period. Data supplied by New York

[1]Dose measured in millirads, converted to millirem by use of an RBE of one. Dose measured with shielded dosimeters and thus represent gamma dose component only.

[2]Measured with open window dosimeter, and therefore represents beta and gamma components.

State reported an average reading of 4.8 milliroengtens per month above background as measured with a pressurized ion chamber along the Cattaraugus Creek on three occasions in 1969.[3]

RESULTS AND DISCUSSIONS

The dose commitments accrued in 1968 to a "typical" and "maximum individual" around Nuclear Fuel Services are presented in table 4. The major dosimetric intake for a "typical individual" was due to ^{90}Sr and ^{137}Cs ingestion in the diet. A dose commitment from dietary ^{90}Sr of 77 millirem and from dietary ^{137}Cs of 1.7 millirem can be compared to dose commitments of 72 millirem and 1.3 millirem, respectively from the intake of these radionuclides during 1968 based on milk samples collected in other parts of New York State (362 samples). Considering analytical and statistical variations in the data, the dose commitment from diet to the "typical individual" around NFS does not differ significantly from that of the average adult population of the rest of New York State and can be attributed largely to fallout. The dose commitment from other radionuclides to a "typical individual," including ^{3}H and ^{85}Kr in air, was less than 2 millirem. When one considers the addition of local fish and deer meat to the diet, it is observed (from table 4) that the ^{90}Sr dose commitment to the "typical individual" is increased by 20 percent and the ^{137}Cs dose commitment doubled.

As previously noted, except for the dose commitment from ^{90}Sr, all of the dose commitments from other radionuclides are essentially delivered in the first year after intake. The total dose delivered in the first year after intake to a "typical individual" is low compared to the Federal Radiation Council recommendation for a suitable sample of the population (500 millirem per year to bone and 170 millirem per year to the whole body) (19). The total dose for a "typical individual" is approximately 1 percent of the FRC's Radiation Protection Guide for bone and less than 3 percent of the Guide for the whole body.

The dose commitments in 1968 were in the same dosimetric range as doses from natural radioactivity (80 to 200 millirem per year), or approximately 2 percent of the dose commitment from natural radioactivity (5,000 millirem in 50 years) (20). This is consistent with data on studies of population in the northeastern United States which found the ^{90}Sr bone dose commitment from fallout over a 7-year period to be 10 percent of the 50-year natural radiation dose (7).

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[3] 6.7 microroentgens/hour x 24 hour/day x 30 days/month equal 4.8 milliroentgens/month. This is in terms of exposure dose rather than absorbed dose since the tissue equivalency of the ion chamber is not known. The AEC data are in terms of absorbed dose (19).

Table 4. Dose commitment accrued in 1968 in the vicinity of Nuclear Fuel Services

Radionuclide	Critical organ	Media	Dose commitment[a] (millirem)	
			Typical individual	Maximum individual
^{90}Sr[b]	Bone	Diet[c]	77	90
		Deer	1.9	227
		Fish	16	[d]215
^{137}Cs	Whole body	Diet	1.7	4.5
		Deer	1.6	[e]200
		Fish	0.2	8.6
^{134}Cs	Whole body	Deer	0.4	48
^{60}Co	G.I. tract	Deer	<0.01	0.2
		Fish	0.05	0.5
^{106}Ru-Rh	G.I. tract	Fish	0.9	16.4
^{3}H	Whole body	Diet	<0.1	0.3
		Deer	0.1	0.3
		Fish	<0.01	0.3
		Drinking water	<0.17	1.0
		Air (Inhalation and skin absorption)	<0.05	0.1
^{85}Kr	Whole body	Submersion in air	0.05	0.3

[a]Dose per 50 years or per lifetime.

[b]For ^{90}Sr ~ 7 percent of the dose commitment to bone delivered is delivered during the first year after intake:
Diet: 5.4 millirem (typical) and 6.3 millirem (maximum).
Deer: 0.1 millirem (typical) and 16 millirem (maximum).
Fish: 1.1 millirem (typical) and 15 millirem (maximum).
For other radionuclides >90 percent of the dose delivered in the first year after intake.

[c]Diet intake indirectly determined through use of radionuclide value reported in milk.

[d]Represents whole fish. The majority of ^{90}Sr concentrates in bone which is usually considered inedible. Therefore the dose commitment may represent a high estimate.

[e]From sample caught onsite.

From table 4 it can be seen that for the "maximum individual" the dietary ^{90}Sr and ^{137}Cs dose commitments in 1968 are higher than for the "typical individual," even though he was assumed to have half the dietary intake (in terms of quantity). This is due to an increase in the maximum concentrations of ^{90}Sr and ^{137}Cs in milk when compared to the average concentrations. More significantly, the ingestion of deer meat and fish increased the dose commitments to the "maximum individual" from ^{90}Sr and ^{137}Cs, and also from ^{134}Cs and ^{106}Ru-Rh.

The additional dose from ^{60}Co is minor. In the case of the "maximum individual" his total dose commitment accrued in 1968 to bone from ^{90}Sr is 532 millirem. However, this includes analysis of whole fish which would tend to overestimate ^{90}Sr intake. To the whole body from ^{137}Cs and ^{134}Cs it is 257 millirem based on meat from a deer trapped onsite. In the first year following intake, the ^{90}Sr dose would be 38 millirem or less than 3 percent of the dose recommendations as they apply to the maximum exposed individual.[4] The whole-body dose from ingestion to the "maximum individual" is estimated to be 50 percent of the dose recommendations for the maximum exposed individual. In addition to the above doses the "maximum individual" might receive a 17 millirem dose to the gastrointestinal tract, the majority of it due to ingestion of ^{106}Ru-Rh in fish. Assuming the "maximum individual" ingested 50 kg of deer meat and 40 kg of fish per year, the data suggest that the maximum intake of deer meat be limited to about 100 kg of deer meat and 300 kg of fish per year. The suggested allowable consumption agrees with recommendation made by others for deer meat (21). It is highly unlikely, based on diet studies, that the allowable intake of fish would ever be consumed.

The contribution of ^{3}H to the whole-body dose commitment of a "maximum individual," both from ingestion and air exposure is minor compared to the above doses. It amounts to 2 millirem, the majority of which is accrued via drinking water. The ^{85}Kr dose due to air submersion is 0.3 millirem. This dose must be considered in light of the assumptions for wind direction, point of exposure, and period of exposure made above.

Data on external radiation exposure indicate a mean gamma dose around NFS of 4 millirem per month above background. This would amount to an additional whole-body exposure of approximately 1.2 millirem for the "maximum individual" who might spend 200 hours per year fishing. This dose is, because of its mode of measurement, mostly gamma and probably results from stream and silt contamination by gamma emitting radionuclides.

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[4] The FRC recommendation for the average of a suitable sample of exposed population group is interpreted to apply to the maximum permissible per capita annual dose received by the public. The FRC recommendation for individuals is interpreted to apply to the maximum exposed individual. For bone this is 500 millirem/year versus 1,500 millirem/year (19). The AEC regulation limit of 500 millirem/year whole body to any individual is interpreted to apply to the maximum exposed individual (22,23).

The above discussion is limited to estimates of dose commitments accrued and avoids delineation of the size of the population at risk. Some preliminary data are available which provide a general idea of the size of the populations involved. Census data (1960) indicate populations of approximately 6,000, 16,000, and 170,000 persons living within a 5-mile, a 10-mile, and a 25-mile radius of the plant respectively (24). Perhaps more significant are data available on the number of hunters and fishermen in the area. It is estimated by the New York State Health Department that three to four dozen hunters are present near the site during hunting season and less than one dozen at other times (25). A survey performed by the Conservation Officers of Regions I and II, New York State Conservation Department (25) during three week days and three Saturdays and Sundays in July-August 1969 indicated heavy fishing pressure in the Springville area (approximately 6 miles from the site) and near the inlet to Lake Erie (approximately 25 miles from the site) when compared to other sites fed by the Cattaraugus Creek. Most fish caught were for personal consumption. At the first site noted above 44 persons were fishing during the survey period, averaging 4 to 10 fishing trips per year. This survey indicated one individual fishes 180 days per year and that maximum consumption might be as high as 160 kg per year. At the second site mentioned 62 persons were fishing during the survey period, averaging 10 trips per year although many individuals averaged 30 to 40 trips per year. It may be expected that more intense fishing pressures occur during the April and May trout fishing season. Furthermore, since the survey covered a short period of time, yearly figures might differ. In any case, the above data, while valuable does not definitively evaluate the size of the populations described in this report.

SUMMARY

The dose commitment concept when applied to a "typical individual" and "maximum individual" in the vicinity of Nuclear Fuel Services provides a simple means of determining significant environmental surveillance data. Based on surveys carried out by the New York State Department of Health, the Bureau of Radiological Health, U.S. Public Health Service, and the Atomic Energy Commission, the dietary dose to the "typical individual" around NFS in 1968 is not thought to differ significantly from that for the average adult population of the rest of New York State and was attributable essentially to fallout. This dose commitment (77 millirem) was approximately 2 percent (in one year) of the dose commitment from natural radioactivity over a 50-year period. When ingestion of typical amounts of deer and fish were added to the diet, the dose delivered in the first year after intake was approximately 1 percent of the FRC recommendations for bone dose (500 millirem per year) and 3 percent of their

recommendations for whole-body dose (170 millirem per year). The presence of Nuclear Fuel Services, based on data presently available, did not significantly increase thy radiation dose to the "typical individual" in 1968 above that due to fallout and natural radiation.

The "maximum individual" was assumed to obtain half his radionuclide intake from a diet containing maximum amounts of specific radionuclides as well as ingesting 50 kg of deer meat and 40 kg of fish per year. For the "maximum individual" the first year dose following ingestion is 38 millirem to the bone from ^{90}Sr or 3 percent of the AEC Regulations.[5] The whole-body dose from ingestion of ^{137}Cs and ^{134}Cs (mostly from deer meat) is 257 millirem or 50 percent of the AEC Regulations. These data suggest that in order not to exceed the AEC Regulations deer meat intake be limited to 100 kg per year. Preliminary data indicate that the external gamma dose above natural background is approximately 1.2 millirem per year to the "maximum individual."

The dose from ^{3}H to a "maximum individual" was 2 millirem while that to the "typical individual" around NFS was negligible. The whole-body dose from ^{85}Kr in air to a "maximum individual" was 0.3 millirem and that to the "typical individual" 0.05 millirem.

Comparisons of dose commitments to FRC recommendations and AEC Regulations raise questions concerning the existence of the hypothetical "typical" and "maximum" individuals, the size of the population at risk fitting these categories, and the suitability of using established guidelines for comparison purposes, especially when population groups are ill defined. These questions, together with knowledge about dietary and living habits of populations at risk, require a more definitive dose study than has already been attempted.

RECOMMENDATIONS

A. POPULATION DOSE STUDY

The purpose of this study would be to realistically define existent population groups on the bases of geographic location, occupation, age, and ethnic and/or cultural differences; and to determine the actual radiation dose to these populations.

1. Define in terms of size and location specific populations at risk.

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[5] As they relate to a maximum exposed individual.

2. Determine the intake of radionuclides (^{90}Sr, ^{137}Cs and ^{134}Cs) to these populations by means of "market basket," "home sampling," and "institutional diet sampling."
3. Determine doses from ^{129}I by analysis of milk samples.
4. Based on the results of the dietary studies, carry out whole-body counting (particularly for ^{137}Cs and ^{134}Cs) of selected individuals.
5. Determine the feasibility of a bioassay program for determination of ^{3}H, ^{90}Sr, and ^{239}Pu in populations around NFS.
6. Determine the radionuclide content of selected human tissues in the above population groups (upon autopsy if and when samples become available).
7. Establish control groups in the Boston area (or other) and simultaneously perform the above environmental sampling and bioassay procedures.

B. CONTINUOUS MONITORING OF THE EXTERNAL ENVIRONMENT AROUND NFS BY MEANS OF FIELD SAMPLERS.

The purpose of this study would be to establish mean and maximum levels of marker radionuclides (^{85}Kr in the air environment, ^{137}Cs, ^{90}Sr, and ^{3}H in the aqueous environment) by continuous field monitoring. Studies during FY 70 were done to establish that these specific radionuclides are of dosimetric importance. Investigations of the feasibility of field samplers now make it possible to continuously, automatically monitor the air environment and/or sample the aqueous environment.

1. Establish a suitable number of automatic continuously monitoring ^{85}Kr air stations in the area of NFS. In addition, in the predominate wind direction establish an automatic monitor for ^{3}H.
2. Obtain a suitable monthly particulate stack air sample for ^{3}H.
3. Establish a suitable number of automatic weir and ion exchange type stream samplers at pertinent locations. These to be collected monthly and the appropriate analysis performed.
4. Relate time release versus location versus concentration for the marker radionuclides in the two environmental media.

C. RADIONUCLIDE LEVELS IN WILDLIFE

The purpose of this study is to investigate the maximum and average levels of dosimetrically important radionuclides in wildlife and fish commonly hunted and ingested around NFS and to establish their radionuclide levels in relation to their range from NFS.

1. Establish which game is important around NFS, the range of this game, and the size of the human population at risk from ingestion of wildlife and fish.
2. Establish proper sampling at various distances from NFS in the forest and stream environments.
3. Perform radionuclide determination for ^{137}Cs, ^{134}Cs, ^{106}Ru-Rh, and ^{90}Sr on the edible portions of wildlife game and fish.
4. Establish the size of human population at risk to this type of exposure and the degree of exposure.

The duration of the above studies is estimated to be 2 years after initiation. Completion of an in-depth population dose study, a continuous field monitoring environmental program, and a radionuclide level in game evaluation should more properly define the actual and potential human radiation doses due to operation of a nuclear fuel reprocessing plant.

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